Non-prompt Muon Study

Introduction

This report summarizes the results from analyzing T1•T3 triggers to extract muon tracks recorded during the normal data conditions. A comparison is made between the muon data taken with the half-density target to the data taken with the (normal) full-density target. There are four runs with the half-density target taken on the final day of the experiment, and the number of neutrino interactions with the half-density target is 20 of which only 5 are ν_μ CC interactions.

If there is a strong connection between the muon tracks originating in π decay from the T1•T3 triggers, and the *neutrino* interactions from π decay, then the non-prompt fraction of the neutrino beam can be extracted by using the ratio, *r*, of the half-density target and the full-density target.

$$\frac{\mu \text{ rate non - prompt}}{\mu \text{ rate other}} \equiv f_{np} = \frac{1-r}{r-2} \; ; \quad \text{where } r = \frac{\frac{1}{2} \text{ density } \mu \text{ rate}}{\text{full - density } \mu \text{ rate}}$$

The connection between the muon flux and the interacted neutrino flux can be strengthened by restricting the muon sample to those tracks that are high-momentum and have a small angle relative to the beamline. In practice, restricting the angle to $\theta < 0.060$ (the "eyes") also guarantees the energy is high, since the muons must penetrate many meters of steel shielding which is directly upstream of the trigger counters. If it were provable that the additional muon flux with the half-density target were directly proportional to the additional ν_μ interactions, then the above estimate is limited only by statistics.

Although it is obvious that high-energy muons originating in π decay give a good measure of the high-energy ν flux, there is no direct experimental proof, and one must rely on Monte Carlo calculations to give a quantitative relation between the μ spectrum and ν spectrum. Here we appeal to the fact that the non-prompt ν_μ CC interactions in the emulsion are predicted to have a very similar spectrum to that of the prompt interactions.

Results

The results from all four runs with the half-density target and four runs with the full-density target are summarized in Table 1. The half-density runs are 3356, 3357, 3358, 3359 and the full-density runs used were taken just prior to switching the beam dump: 3345, 3349, 3350, 3351.

The average momentum of the muons from the half-density sample is 42 GeV/c and the spectrum is shown in Figure 1. A curious feature is that 34 of the 41 events have a positive muon and only 7 are negative. The distribution of these muons in angle-space is shown in Figure 2, along with the 60 mrad cut. This clearly shows the "eyes", with the positive "eye" more populated as usual. The corresponding angular distribution for the full-density sample is seen in Figure 3.

Conclusions

From the Table 1, the beam normalized rate for small-angle muons is $7.6 \pm 1.2 \times 10^{-15}$ per *pot* for half-density and $5.8 \pm 0.7 \times 10^{-15}$ for full-density. Thus, the ratio, $r = 1.31 \pm 0.26$, where the quoted errors are statistics. Using these values for r and its uncertainty, $f_{np} = 0.45$ with a range of [0.05 to 1.33] for a change of one standard deviation in r . Physically, r is bounded by 0 and 2, but the value of f_{np} can be between 0 and ∞ . It is unfortunate that pre-scaled T1•T3 trigger rate was so low, but there is *some* information in this data. The result indicates that non-prompt events cannot dominate

RUN	*pot*	N_μ
3345	2.50×10^{15}	14
3349	2.64×10^{15}	16
3350	3.00×10^{15}	13
3351	2.60×10^{15}	19
Σ (full-density)	10.74×10^{15}	**62**
3356	1.56×10^{15}	8
3357	1.88×10^{15}	18
3358	1.43×10^{15}	9
3359	0.56×10^{15}	6
Σ (half-density)	5.43×10^{15}	**41**

Table 1. The data from the full-density (*top*) and half-density (*bottom*) runs

the neutrino interaction data (as an upper limit to r). The lower limit doesn't really exist since the nonphysical region of $r < 1$ is only 1.2 σ away. The actual level of non-prompt events in the neutrino interaction data cannot be resolved with the half-density data, either directly or indirectly (in this note). The most accurate method for determining the fraction of non-prompt ν_μ CC events is probably by identifying ν_μ and ν_e events and comparing rates from these two processes.

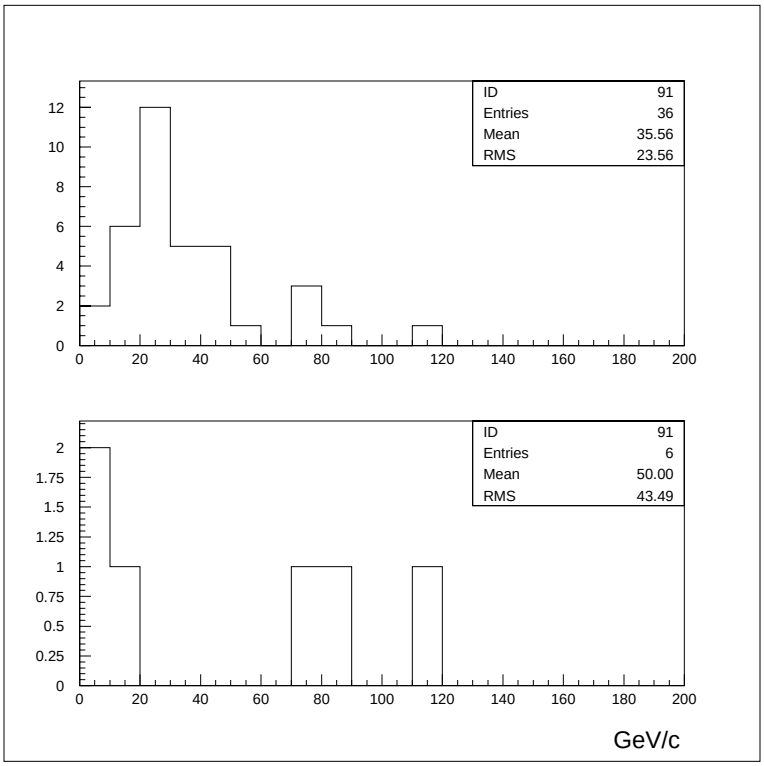

Figure 2. The momentum spectrum for the positive (*top*) and negative (*bottom*) muons fromthe half-density target.

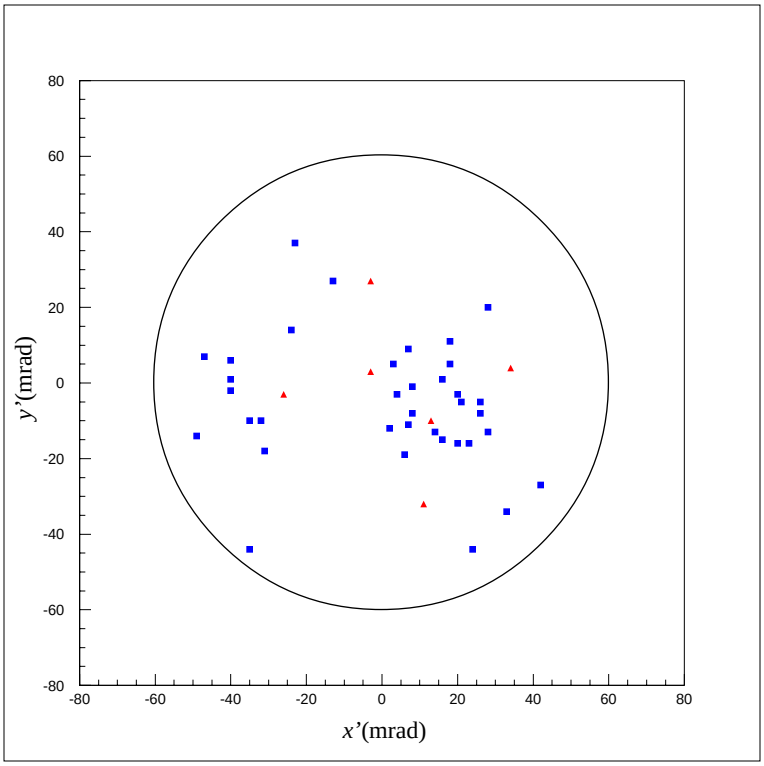

Figure 3. The distribution of muon events in the half-density beam dump. The blue squares are positive muons and the red triangles are negative. The 60mr cut is shown.

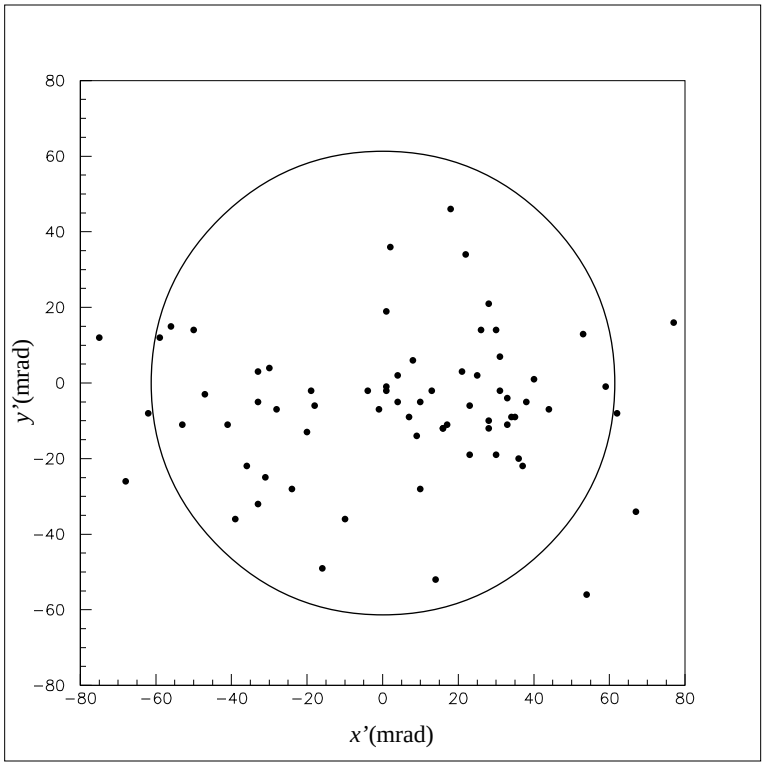

Figure 4. The distribution in angle of the small-angle muon events for the full-density beam dump. Only events within 60mr were used in the sample.